Distributed Energy Technology Characterizations

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2003 Distributed Energy Peer Review

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Technology Characterization Objectives

- Provide an objective and consistent summary of current cost, performance and emissions characteristics of DG systems
  - Reciprocating Engines
  - Gas Turbines
  - Microturbines
  - Fuel Cells
- Provide a projection of cost and performance through the year 2030
  - Based on conventional (“business as usual”) technology trends

Project Team

- National Renewable Energy Lab (NREL)
- Antares Group
- Energy and Environmental Analysis (EEA)
- PERI
- Gas Technology Institute (GTI)

Technology Characterization Process

- Preliminary drafts based on compiling and reviewing best available information.
- Internet peer review by stakeholder community from Jan – Mar, 2003
- Technical Workshops to review and discuss current and projected cost and performance data
    - Manufacturers
    - Component suppliers
    - Industry experts
- To be published as a single document under the joint sponsorship of DOE and GRI (GTI)

Scope of the Technology Characterization

- Profile of current technology status (2003)
  - Technology description
  - Cost, performance and emissions characteristics over applicable size range (nominally-sized systems)
  - Brief discussion of key performance and cost factors
- Projection of cost and performance through the year 2030
  - Identify primary technology paths and technical hurdles
  - Projections based on “business as usual” - ongoing industry and DOE programs

Key Elements

- Cost and performance profiles of nominal systems
  - Based on representative products
  - Span the size range of DG applications
- Electric-only and CHP applications
- Capital Cost
  - Equipment and installation
- Heat Rate/Efficiency
  - Electric output
  - Overall electric and thermal output for CHP
- O&M costs
- Availability & Economic Life
- Emissions

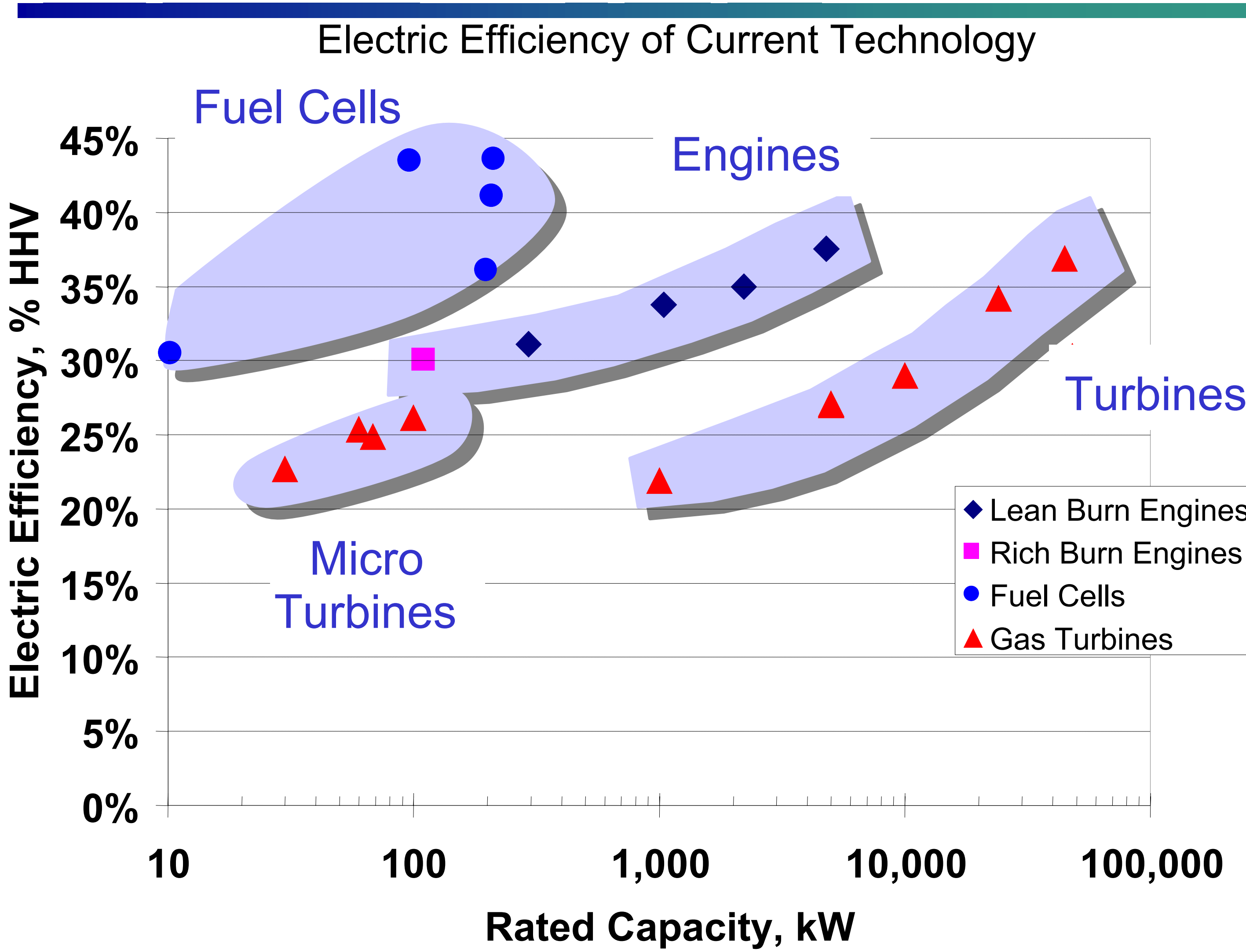
Current Status – Performance

- Performance estimates based on manufacturers' product specs and published targets
- Heat rate/efficiency expressed in Higher Heating Values, net of parasitics and generator losses
- Thermal energy recovery based on manufacturers' specs and/or calculated from exhaust gas flows and temperatures

Current Status – Recip Engine Performance

Capacity (kW)	System 1 100 kW	System 2 300 kW	System 3 1 MW	System 4 3 MW	System 5 5 MW
Engine Combustion	Rich	Lean	Lean	Lean	Lean
Installed Cost, Power-only (2003 $/kW)	1,050	790	720	710	695
Installed Cost, CHP (2003 $/kW)	1,350	1,160	945	935	890
O&M Cost (2003 $/kWh)	0.018	0.013	0.009	0.0085	0.008
Electric Efficiency, LHV	33%	34%	38%	39%	41%
Electric Heat Rate (Btu/kWh), HHV	11,500	10,967	10,035	9,700	9,213
Electric Efficiency, HHV	30%	31%	34%	35%	37%
Engine Speed (rpm)	1800	1800	1200	900	720
Exhaust Heat Recovery (MMBtu/hr)	0.3	0.89	2.11	5.48	9.63
Total Heat Recovery (MMBtu/hr)	0.56	1.52	3.7	9.84	16.7
Power to Heat Ratio	0.61	0.67	0.92	1.04	1.02
Overall CHP Efficiency	78%	77%	71%	69%	73%

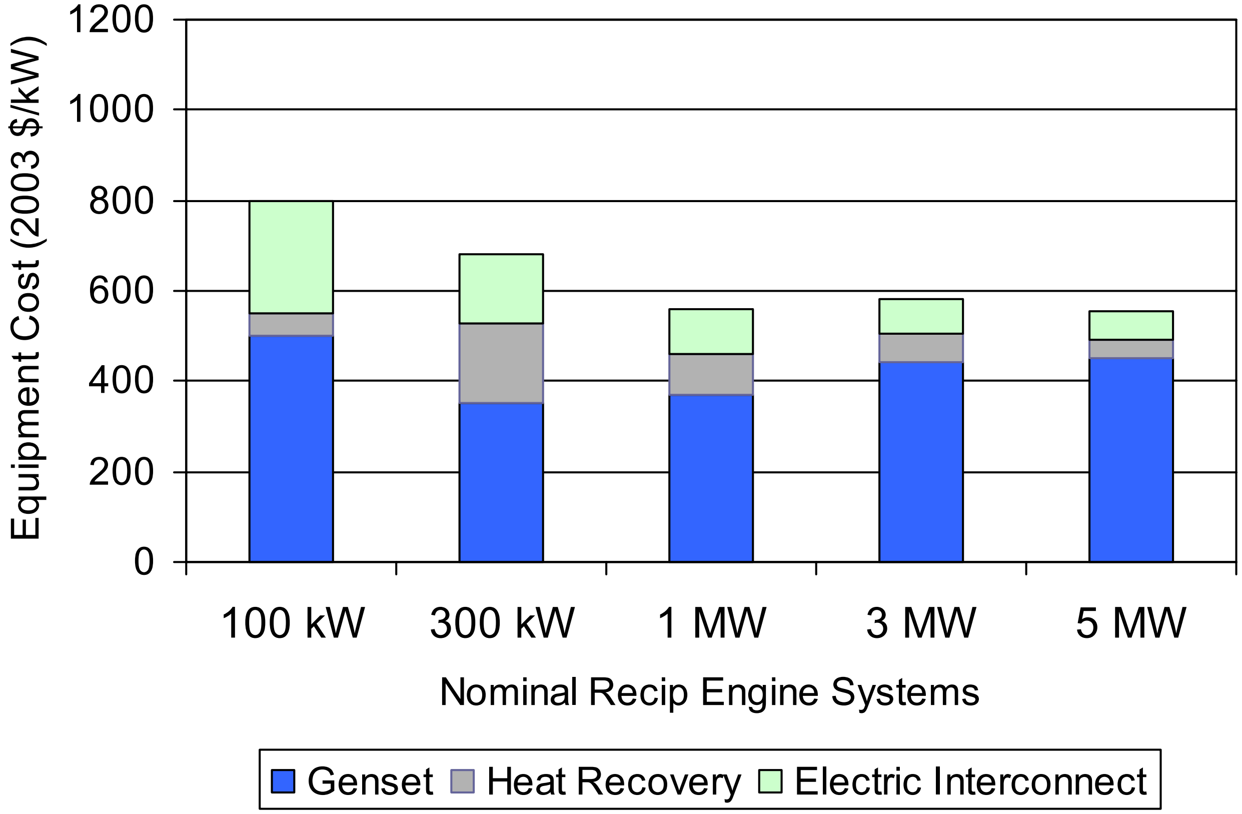
Efficiency of Today's DG Technologies



Current Status – Costs

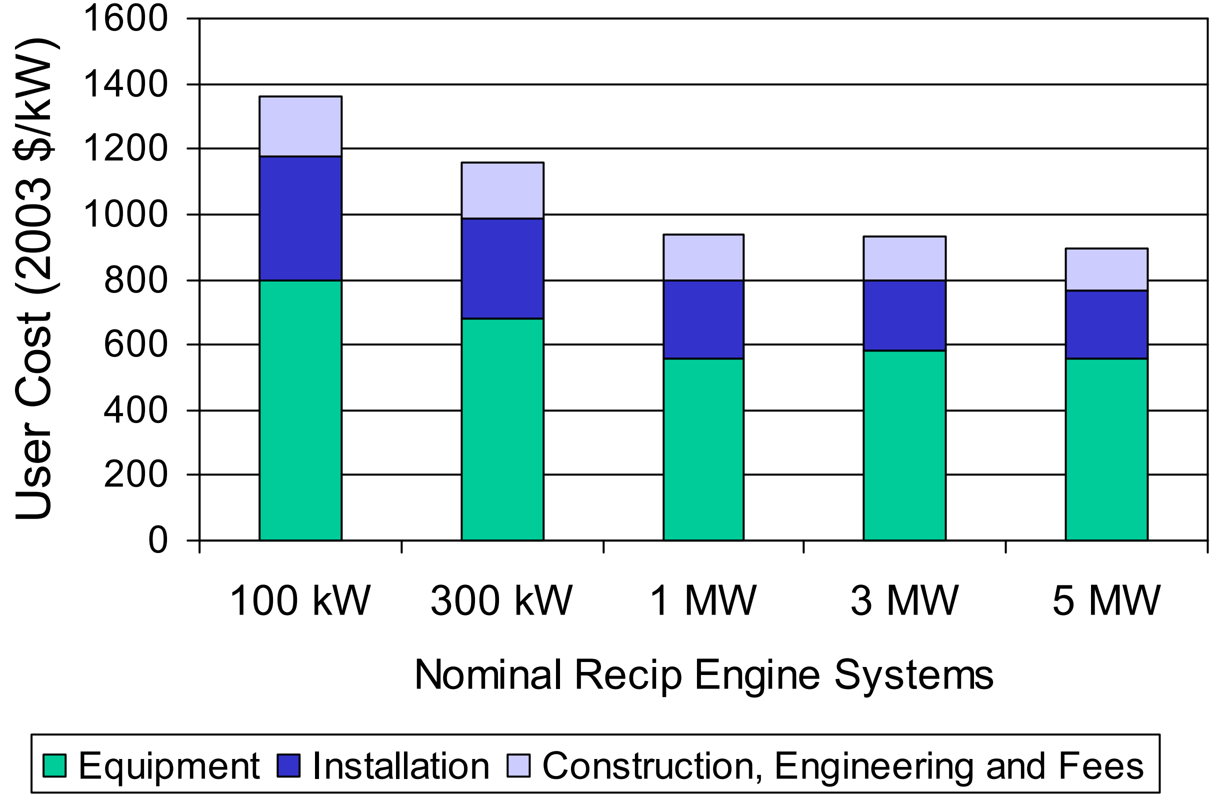
- Equipment costs based on <u>manufacturers’ price estimates</u> (public information) – cost to end-user
- Installation costs based on manufacturers’ data, review of recent installations, and internal experience .
- Installation estimates based on:
  - Minimal site preparation
  - No exhaust aftertreatment
  - Parallel to grid
- O&M costs based on manufacturers’ estimates and engineering analysis

Current Status – Recip Engine Equipment Costs for CHP Applications*



* Costs to user

Current Status – Recip Engine Total Installed Costs for CHP Applications

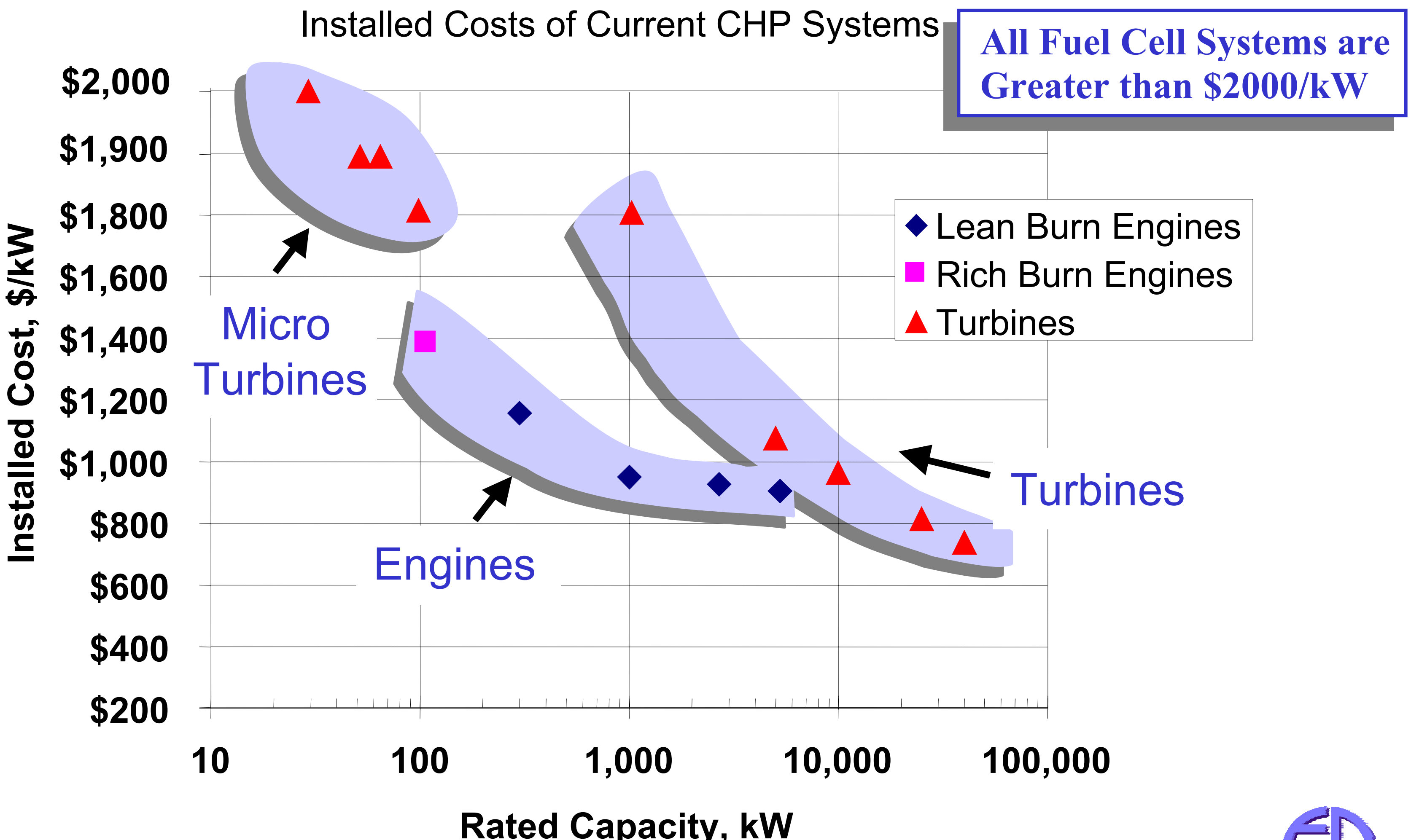


Current CHP Status –Capital and O&M Costs

	System 1 100 kW	System 2 300 kW	System 3 800 kW	System 4 3 MW	System 5 5 MW
Engine Generator Cost ($/kW)	500	350	370	440	450
Heat Recovery ($/kW)	inc	180	90	65	40
Electric Interconnect ($/kW)	250	150	100	75	65
Total Equipment ($/kW)	***750***	***680***	***565***	***580***	***555***
Labor and Materials ($/kW)	412	306	240	220	210
Project and Construction Mgmt. ($/kW)	75	70	56	58	54
Engineer and Fees ($/kW)	75	70	56	49	43
Project Contingency ($/kW)	38	34	28	28	28
Total Plant Cost ($/kW)	***1,350***	***1,160***	***945***	***935***	***890***
Non-Fuel O&M ($/kWh)	**0.018**	**0.013**	**0.009**	**0.0085**	**0.008**

Constant 2003 $

Today's Installed Costs for CHP



Current Status – Emissions

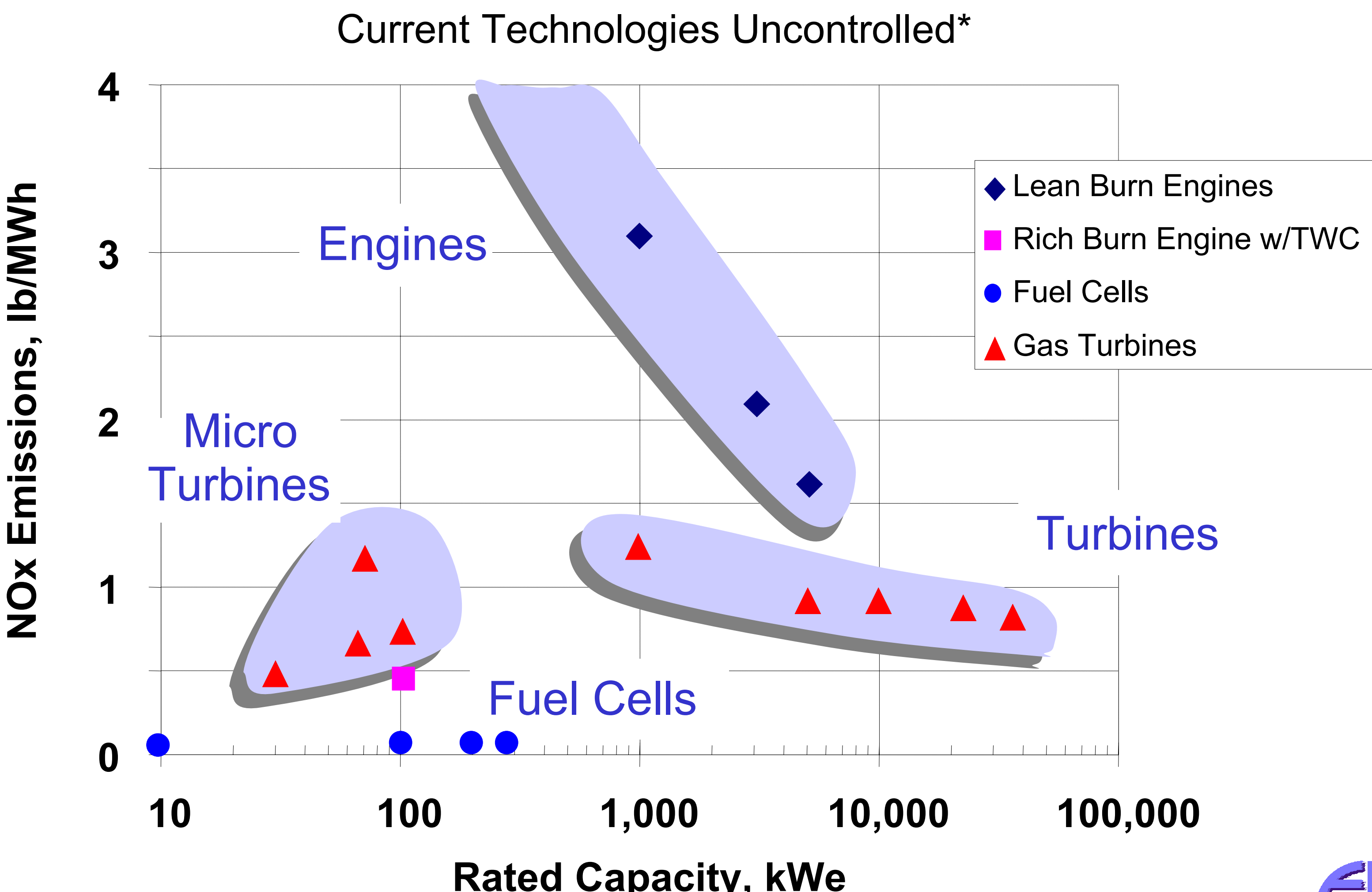
- Based on manufacturers' "guaranteed" emissions rates (actual emissions are generally lower)
- Full load estimates
- There are "exceptions" to the typical emissions rates (e.g., Kawasaki 1.4 MW Xonon @ 3 ppm)

Current Status – Recip Engine Emissions*

Capacity (kW)	System 1 100 kW	System 2 300 kW	System 3 1 MW	System 4 3 MW	System 5 5 MW
Efficiency (%), HHV	30	31	34	35	37
NOx Emissions (g/bhp-hr)	15	2.0	1.0	0.7	0.5
NOx Emissions (lb/MWh)	46	6.2	3.1	2.2	1.6
CO Emissions (g/bhp-hr)	12	2.0	2.0	2.5	2.4
CO Emissions (lb/MWh))	37	6.2	6.2	7.8	7.4
VOC Emissions (g/bhp-hr)	0.7	1.0	1.0	1.3	0.5
VOC Emissions (lb/MWh)	2.2	3.1	3.1	4.0	1.6
CO2 Emissions (lb/MWh)	1,345	1,285	1,175	1,135	1,080

* Without exhaust aftertreatment

Uncontrolled NOx Emissions

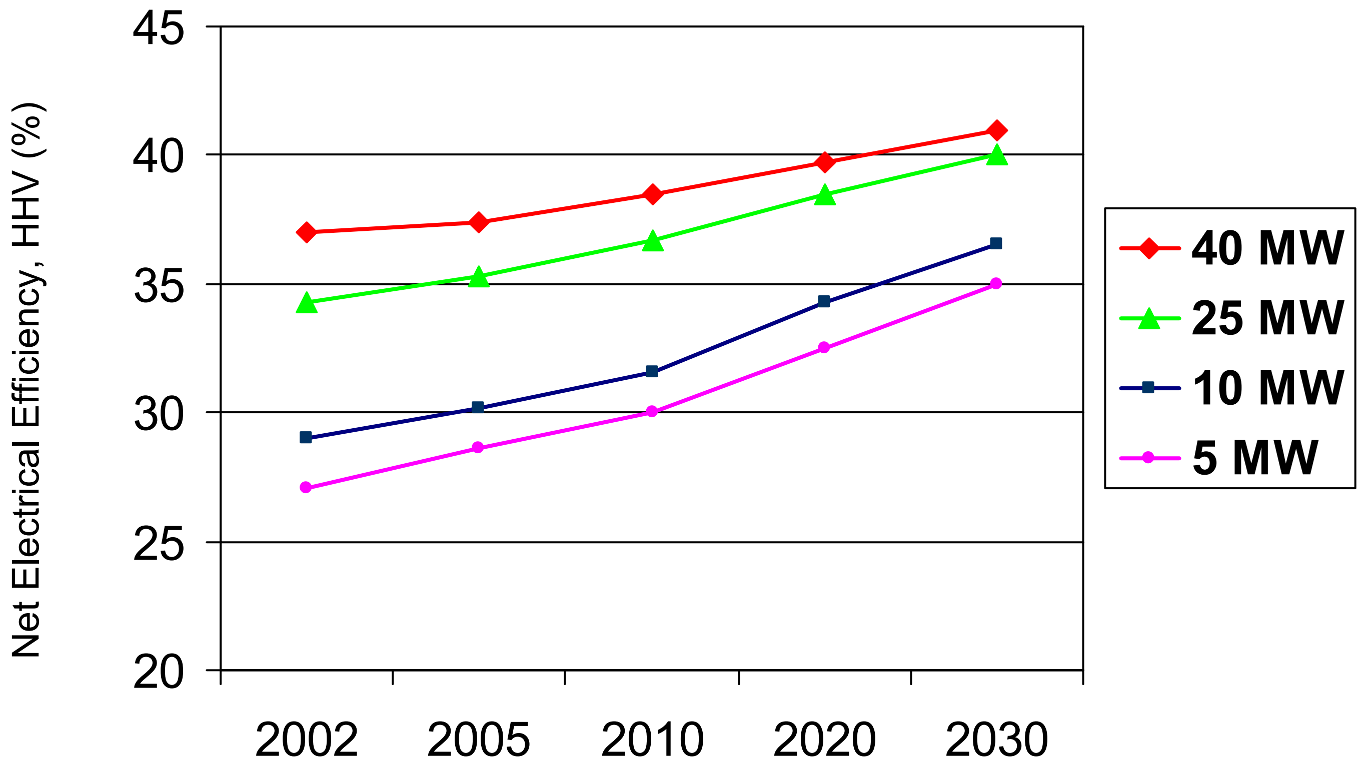


* Rich burn engine includes three way catalyst

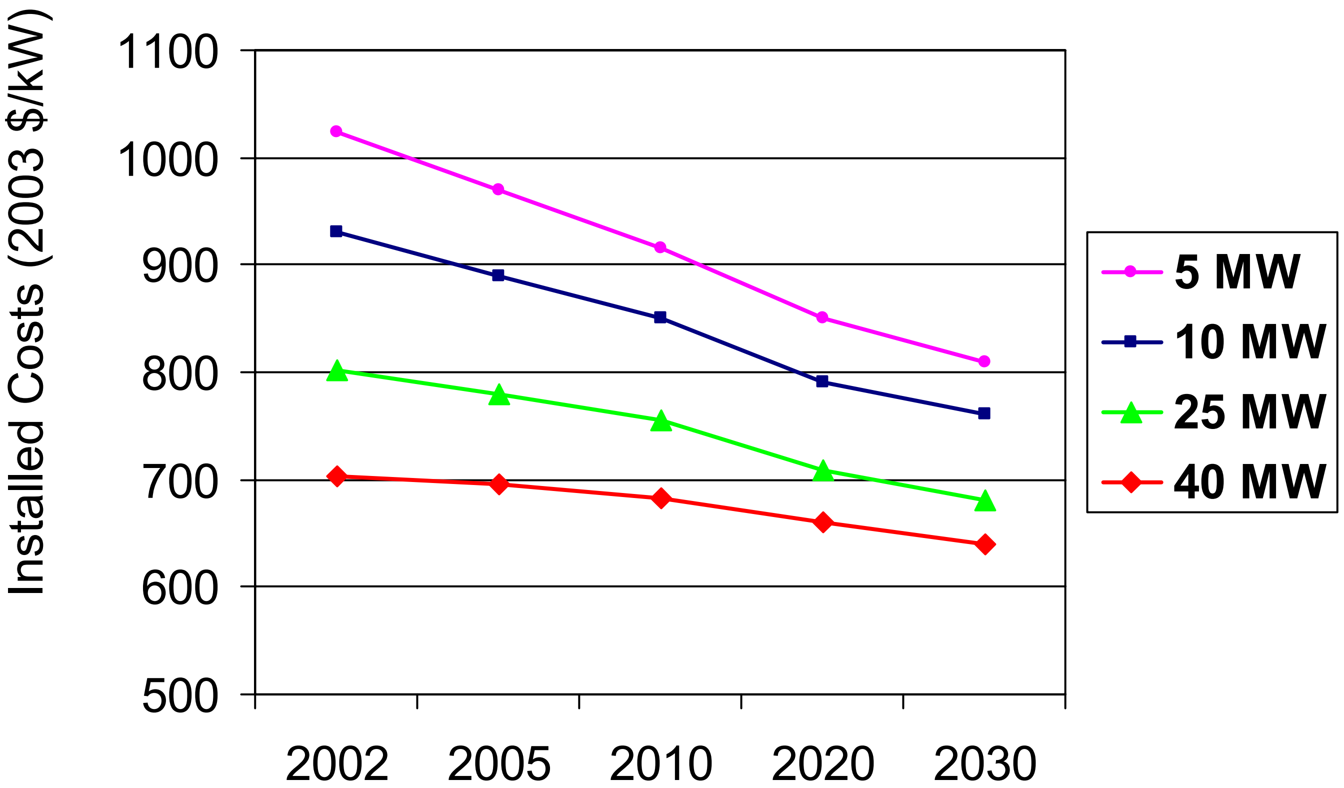
Gas Turbines – Key Technology Issues

- Improve gas turbine efficiency and power
  - Increase turbine inlet temperature and pressure ratio (>3MW)
  - Recuperated systems and/or other approaches for smaller turbines
- Maintain compliance with tightening emissions standards
- Maintain high reliability/durability/maintainability
- Maintain manufacturability
- Optimize thermal recovery

Technology Projection – Efficiency



Technology Projection – Installed Costs



Recip Engines – Key Technology Issues

- Evolutionary improvements will continue to result in gradually declining capital and maintenance costs for recip engines
- Reliability and durability will also continue to improve over time
- Emissions is the critical challenge confronting recip engines in the future
- The key to future market success will be to reduce emissions without negative effects on efficiency, cost, reliability, maintainability and manufacturability

Microturbines – Key Technology Issues

- Reduce capital costs
  - Equipment and installation
- Improve electric efficiency and power output
- Maintain emissions compliance
- Demonstrate reliability/durability
- Verify O&M requirements

Fuel Cells - Key Technical Objectives

- Durability of stacks and components
- Integration of reformer technology
- Sensitivity to fuel impurities
- Power conditioning efficiency
- Effectiveness of thermal and water recovery
- Balance of plant optimization
- Effective packaging and process integration
- Specific issues inherent with each fuel cell type

Summary

- Consistent, objective summary of current cost, performance and emissions characteristics of DG systems
- Distinction between established products and emerging technologies
- Projections for 2005, 2010, 2020 and 2030 based on conventional technology track and expected funding levels
- Parallel efforts through ORNL to develop characterizations of thermally activated technologies (desiccants, absorption chillers)